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ABSTRACT

The purpose of this brief is to draw from the findings of the 1990 Reform Up Close study of high school mathematics and science in six states by the Consortium for Policy Research in Education in order to: (1) characterize standard-setting policies in high school mathematics and science, (2) document the effects of these standard-setting policies on the math and science curriculum as experienced by students, and (3) compare the nature of the enacted curriculum to the desired curriculum as reflected in documents of today's curriculum reforms. It was found that the content of mathematics and science courses appeared not to have been compromised by increased enrollments, but the instruction still looked quite traditional. (MKR)

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CPRE Policy Briefs

by
Andrew C. Porter
and
Associates

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CPRE POLICY BRIEFS
Reporting on issues and research in education policy

Reform of High School Mathematics and Science and Opportunity to Learn

by Andrew C. Porter and Associates

This policy brief concerns the nature of the high school mathematics and science curriculum in the United States. It draws from a large study which documented instructional practices and content (the enacted curriculum) using novel methodologies.[1] This research approach is a promising step toward the development of indicators of opportunity to learn (see sidebar on page 9). The study also provides encouraging news about the effects of increased standards in math and science—they did not result in a watering down of the curriculum. However, practice in the schools studied is a far cry from the ambitious goals for math and science instruction now being developed by the profession.

Background

The early 1980s were years of intense criticism of the productivity of the education system in the United States. These criticisms gave rise to a host of standard-setting activities, many of which began in the mid-1980s and continue to the time of this writing. Lagging achievement in science and mathematics was a special target for concern, as reflected by National Educational Goal 4, "By the year 2000, U. S. students will be first in the world in science and mathematics achievement" (U. S. Department of Education 1990, 5).

As states, universities, school districts, and schools took steps to increase the standards they set for students, others began to worry about the possible unintended consequences. What if higher standards for high school graduation, both in terms of course requirements and performance standards, led to increases in dropout rates? What if gains from the equity initiatives of the 1960s and 1970s were to fall victim to the standard setting activities of the 1980s?

Those who expressed reservations about increasing education standards first hypothesized that, as a result of increased standards, high school graduation rates would decrease, dropout rates would increase, and these negative results would be especially true for minority and poor students. At least to date, that hypothesis has not come true (U. S. Department of Education 1992).

When the feared retention problem did not materialize, a second concern emerged. Was it possible that schools were accommodating students by allowing them to meet the new standards through remedial and basic courses? To address this possibility, Clune and White (1992) analyzed transcript data on changes in course-taking patterns among graduates of high schools enrolling mostly lower achieving students in four states that had increased their high

[1]The research reported in this report was supported by the Consortium for Policy Research in Education through a grant from the National Science Foundation (Grant No. SPA-8953446) and by the Wisconsin Center for Education Research, School of Education, University of Wisconsin-Madison. The authors are solely responsible for the views expressed here.

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school graduation requirements. They found that credits completed in academic subjects did increase by a substantial one-half year of instruction on average and that the additional academic credits completed were in courses of varying levels of difficulty, not just in remedial and basic level courses.

For those who doubted the benefits of increased standard setting, however, there remained yet a third hypothesis. What if, after standards were increased, the actual instruction in courses was weakened? What if the increases in numbers of students taking algebra, for example, resulted in a watered down algebra curriculum to accommodate the weaker and less motivated students? It was exactly this third concern that served as the primary motivation for CPRE's 1990 *Reform Up Close* study of high school mathematics and science funded by the National Science Foundation (Porter et al. 1993).

The purpose of this brief is to draw from the findings of that study to (1) characterize standard-setting policies in high school mathematics and science, (2) document the effects of these standard-setting policies on the math and science curriculum as experienced by students, and (3) compare the nature of the enacted curriculum to the desired curriculum as reflected in documents of today's curriculum reforms.

Design and Sample

Six states were selected based on their ability to provide contrasts in curriculum policy formulation, although all six had significantly increased math and science high school graduation requirements in the 1980s. California and Arizona represented two states already at work on trying to reform curriculum to place greater emphasis on higher-order thinking and problem-solving. They were pursuing these goals using a variety of strategies. In contrast, Florida and South Carolina were two states with fairly comprehensive curriculum control strategies aimed at guaranteeing basic skills. Missouri and Pennsylvania stood between these extremes in that they were relatively inactive in terms of providing any type of curriculum leadership.

In each state, two districts were selected, one large urban and one smaller suburban/rural. This allowed investigation of curriculum policymaking in both large- and small-district bureaucracies. In the urban districts, two high schools were studied so that within-district school variability could be determined. In the smaller district, only one high school was studied; in some of the districts, only one high school existed. Throughout, the focus was on schools serving high concentrations of low-achieving students from poor families.

For describing the enacted curriculum, teacher's daily logs of instruction were obtained from two math and two science course sections in each high school. Courses were selected because of large enrollment gains since state increases in high school graduation requirements. The sample of log data represented 62 course sections with a median of 165 instructional days. In addition, math and science teachers in the 18 schools studied were surveyed via a written questionnaire. Classroom observations and teacher interviews completed the data collection strategies for describing the enacted curriculum. Interviews were conducted at the school, district, and state levels to characterize curriculum policies and their perceived effects.

The data set for analysis was large and complex, consisting of 18 interviews of state education agency staff, 44 interviews of district administrators, 76 interviews of school administrators, and 81 interviews of teachers. Also, 116 classroom observations, 312 teacher questionnaires, and teacher logs on 62 course sections were analyzed.

The logs provided data on the enacted curriculum that was in high agreement with independent reports from classroom observations. Questionnaire data, in turn, was seen to correlate well with teacher log data, while requiring substantially less cost and respondent burden. The study showed it is possible to monitor the enacted curriculum on a fairly large scale (Smithson and Porter 1994).

Standard Setting Policies in 1990

Our *Reform Up Close* study of high school mathematics and science took place at a time of great transition. The basic skills focus of curriculum policies in the 1970s were giving way to a focus on providing instruction in higher-order thinking and problem-solving for all students. Professional associations had begun the curriculum standard-setting process, with the National Council of Teachers of Mathematics in the lead. Some states were ahead of the professional associations; in our sample California was the best example. But not all states were in the same place in the transition from basic skills to ambitious content for all students. In our sample, Missouri and Pennsylvania, relatively inactive states in the prior basic

skills movement, had not yet picked up the mantle for the new reform either. South Carolina and Florida, two examples of states providing leadership in guaranteeing basic skills for all students, found themselves caught in a bind. Just when they had in place well-functioning basic skills curriculum policies, the nation decided to move toward a new goal of ambitious content for all students. At the time of our study, these states were beginning to talk about changing their systems, but with their heavy reliance on basic skills mandates, much work needed to be undone.

Because states, districts, and schools were in a transition period, moving from one curriculum reform to another, 1990 was a time of great inconsistency among policies. Curriculum frameworks appeared to be the policy instrument of choice for states and districts moving toward the goal of ambitious content for all students. California and Arizona both had curriculum frameworks consistent with this goal.

We also detected a transition in the style of curriculum policy formulation. As the goal shifted from one of guaranteeing minimum basic skills to one of higher-order thinking and problem-solving, the style of policy leadership appeared to be shifting from controls and mandates to persuasion.

California's curriculum framework was not required, nor were there clear rewards and sanctions later attached to California's new assessment program. Increasingly, teachers were being involved in significant ways in policy formulation and development. Teachers always have had an important role in textbook adoption in California, and in some cases have been significantly

involved in developing curriculum frameworks and guides. But in our states and districts in 1990-91, there was significant teacher involvement in nearly every policy initiative at every level of the formal school hierarchy. This movement in curriculum leadership, away from control and toward persuasion, seemed to be a very positive development. Curriculum policies in which teachers have had significant involvement are likely to be authoritative and convincing. Their effects are likely to be both longer lasting and more consistent with the intended goals (e.g., Porter 1989).

Not only was 1990 a period of transition in curriculum policy formulation, it was also a time during which states, districts, and schools differed sharply one from another in the nature and extent of their curriculum policy leadership. There were some patterns, however. Districts tended to find state curriculum leadership helpful, especially the large urban districts. In California, where state frameworks emphasized ambitious content for all students, the urban district was trying to eliminate tracking in its schools. The same was true for Arizona and the large urban district there. In South Carolina, state basic skills and testing initiatives were strengthened substantially by district tests designed for selected courses and which students were required to pass to receive course credit. Florida's curriculum control basic skills initiatives were enhanced substantially by the Florida urban district's policy of giving monetary bonuses to schools and teachers exhibiting good test performance. In contrast, our rural districts, with their substantially smaller bureaucracies but not necessarily less pressing problems, tended to take a minimalist approach to curriculum leadership. In some cases, these rural districts were so small that distinguishing between district and high school policies was impossible.

Standard-Setting in the Sample

Because curriculum policies provide flexibility and room for interpretation, school-level response frequently determines the

degree of upgrading that actually occurs. In the Arizona urban district, one of the two high schools studied required all students to take a first-year algebra course and a first-year chemistry/physics course. The curriculum of these courses was standardized through school-level curriculum guides and school-level staff development. Similarly, the high school in the smaller urban district in Pennsylvania had moved to eliminate all basic courses in math and science. It was requiring that nearly all freshmen take algebra. In the urban South Carolina district, one of the two high schools was following the district's lead to push increasing numbers of students into college preparatory courses. In contrast, teachers in the other school had convinced the principal that increasing enrollment in college preparatory courses was not a useful strategy and would not benefit students.

Two of the most frequently mentioned curriculum policy instruments deserve special mention. Textbooks and tests are important instructional resources that can and often do influence the nature of high school mathematics and science instruction.

Textbook adoption does not appear to have been a particularly forceful curriculum control policy in high school mathematics and science. Of our six states, only South Carolina and Florida had textbook adoption policies that applied to high schools. Both states left significant choice to the district. Some districts had adopted a single text for each high school mathematics and science course offered. Typically, these were the small rural districts where there is only one or possibly two high schools in the district.

The real story to be told about instructional materials, however, is not about the ways in which they were being used by states and districts to control local practice. Rather, the most significant point is that instructional materials to support the curriculum reform of ambitious content for all students were simply not available. Hopefully the publishing industry will respond to the reforms by providing needed materials. If they do not, curricular reform is almost sure to fail. No matter how often and by whom teachers are admonished to develop their own materials and not be textbook followers, most teachers feel that they have neither the time nor the expertise to offer instruction without a supporting text.

Testing also plays a unique role as an instrument of curriculum policy control in high school math and science. First, most states and districts tested mathematics in high school, but substantially fewer tested in science. Thus, mathematics was a much more regulated curriculum in high school than was science. This remains true today. Second, in the two states with high school graduation tests, South Carolina and Florida, the effect of the tests was to increase the number of remedial courses and the amount of remedial instruction received by students. Since, in both states, mathematics was a part of the high school graduation test and science was not, more remediation was seen in mathematics than in science. Whether or not this was a positive development for students is unclear. On the one hand, many of the students receiving remedial instruction did eventually get to the point where they could pass the test and graduate. On the other hand, the material tested was material that students should have mastered by sixth grade. In some sense, then, students limited to remedial instruction are not receiving a high school education in mathematics.

The Influence of Standard-Setting Policies in Mathematics and Science on Student Opportunity to Learn

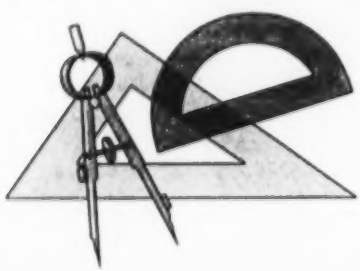
The information collected through daily teacher logs and the information collected through teacher questionnaires allow a comprehensive and detailed description of high school mathematics and science instruction in our six states, at least as taught in high schools serving high concentrations of low-achieving students. The questionnaire data represent all mathematics and science courses and all mathematics and science teachers in the high schools studied. In contrast, the log data are more selective, providing detailed descriptions of the enacted curriculum for courses experiencing the largest gains in enrollment following increases in math and science graduation requirements.

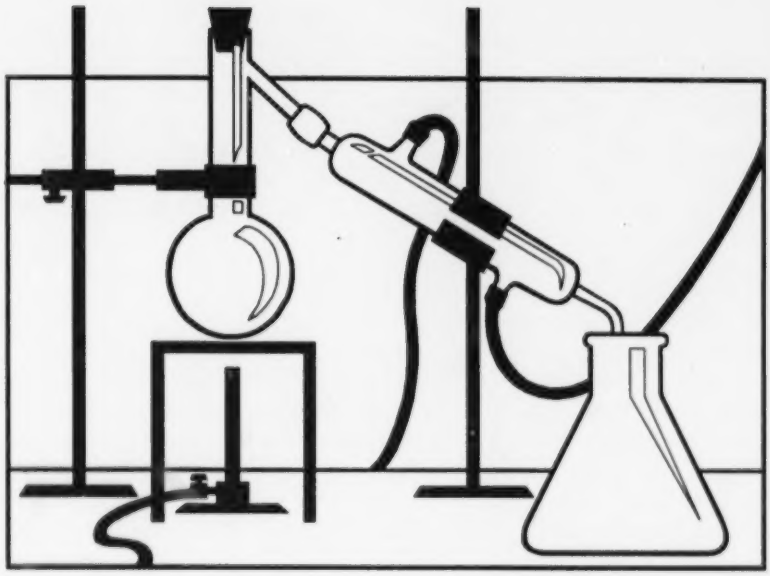
By comparing the enacted curriculum as described by the questionnaire data to the enacted curriculum as described by the enrollment-gaining courses in the

log data, it is possible to see whether or not increases in enrollment compromised the curriculum in either math or science. If large influxes of new students, presumably less qualified, did bring about a "watering down" of the curriculum, then the courses described by log data would look weaker than courses with the same titles in the larger questionnaire sample. Two of the math courses, both Algebra 1, were in schools that required all students to take Algebra 1. One of the science courses, Chemistry/Physics, was in a high school that required it of all students. Comparing these required courses to other courses in the log sample with the same titles but not required of all students provides a second check on the "watering down" hypothesis.

For each type of math and science course, comparisons of the questionnaire sample to the log sample uncovered only minor differences in what was taught. Thus, the more heavily subscribed log sample courses showed few, if any, signs of being weaker than the questionnaire courses taken by fewer students. For example, the content of Algebra 1 looked much the same, regardless of whether or not the Algebra 1 section was in a school where Algebra 1 had experienced large increases in enrollment. Biology looked much like Biology regardless of the percentage of the student body taking the course.

The three required courses in the log sample provide a somewhat



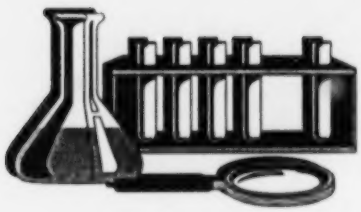


stiffer test of the hypothesis that the curriculum upgrading strategy of increasing enrollments in advanced courses results in those courses being watered down. For the two Algebra 1 courses required of all students, one emphasized algebra (as opposed to other content areas such as arithmetic) even more than was true for the average of all Algebra 1 courses in the log sample. The other required Algebra 1 course emphasized algebra only slightly less than the average for all Algebra 1 courses.

When looking more closely at the types of algebra topics emphasized, both required courses put greater emphasis on advanced topics than was true for the average of all Algebra 1 courses. The required Algebra 1 course with the greatest emphasis on algebra topics also put an unusually high emphasis on nonlinear equations. The other required Algebra 1 course placed a higher emphasis on work involving systems of equations, a topic more likely to be taught in Algebra 2 courses than in Algebra 1 courses. Despite the fact that all students were required to take them, both of the two required courses looked much more like Algebra 1 courses than they looked like Pre-algebra courses. Neither course looked anything like General Math.

When extending the analysis of the two required Algebra 1 courses to consider modes of instruction and intended student outcomes, still there was no evidence that the enacted curriculum had been watered down. The two required courses parallelled algebra courses generally in the degree to which instruction consisted of lecture, use of concrete or pictorial models, equations/formulas, graphs or lab work. Both required courses placed a lower emphasis on computation than did Algebra 1 courses in general.

The required course that placed the greatest emphasis on algebra made up for its relatively lower emphasis on computation by stressing student understanding and memorizing facts. The other required Algebra 1 course replaced the typical emphasis on computation with a relatively greater emphasis on solving routine problems (e.g., story prob-



lems). If anything, this finding represents a stronger curriculum for that required course than for Algebra 1 courses in general.

Similarly, for the required Chemistry/Physics course there was no evidence that increased enrollments had weakened the content of instruction. The required Chemistry/Physics course looked almost identical to a college prep Physical Science course in the sample, with both courses devoting 37 percent of instructional time to chemistry, 37 percent to physics, and 24 percent to topics on the nature of science. Within these content areas, the required Chemistry/Physics course placed a greater emphasis on atomic and nuclear structure and energy and less emphasis on chemical properties and processes and organic chemistry than did the college prep Physical Science course. These differences are suggestive not of a watering down, but rather simply of a difference in substantive focus.

The required Chemistry/Physics course relied less heavily on written and oral exposition than either the college prep Physical Science course or Physical Science courses in general. Instead, the required course placed a relatively greater emphasis on work involving pictorial and concrete models (28 percent of instructional time), suggesting that the required course provided a better quality of instruction than either Physical Science courses or the college prep Physical Science course. Similarly, the required Chemistry/Physics course placed less emphasis on students memorizing facts and more emphasis on students replicating experiments than did either the college prep Physical Science course or Physical Science courses in general.

Thus, no evidence was found that requiring more students to take more advanced mathematics and science resulted in compromising the curricula of the courses experiencing the increased enrollments. Algebra 1 remained Algebra 1, regardless of whether all students were required to take it. The required Chemistry/Physics course looked as challenging in terms of topics covered as did the college prep Physical Science course, and the actual quality of instruction looked better.

Professional Standards and the Enacted Curriculum in High School Mathematics and Science

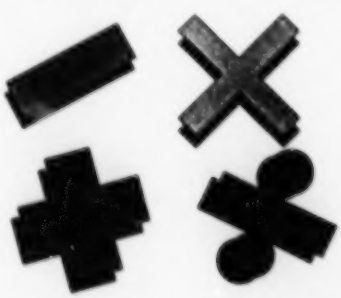
The questionnaire and log data provide a description of the enacted curriculum in high school mathematics and science courses (in high schools serving high concentrations of low-achieving students) at a level of detail not previously available and in a language that facilitates comparisons and contrasts across courses, schools, districts, and states. This rich and comprehensive description of high school mathematics and science classroom practices can be used to compared actual practice to that called for by the reports of professional societies, especially the NCTM *Curriculum Standards* (1989) and the AAAS *Science for All Americans* (1989). Because the initiation of those curriculum reforms roughly corresponded in time to the period of data collection, the descriptions cannot be taken as an evaluation of progress toward realizing those reforms. Rather the descriptions of classroom practice from *Reform Up Close* provide a baseline from which can be seen the types of changes necessary.

What Topics Are Taught

The math courses in the log sample provided few surprises, though some disappointments, about the content of instruction. Basic math courses consisted primarily of arithmetic and measurement, with a few of the basic courses also including significant emphasis on algebra.

Algebra courses were dominated by algebra content. Eighty-three percent of instructional time was on algebra in Algebra 1 courses, and 88 percent of instructional time was on algebra for Algebra 2 courses. Pre-algebra stood midway between basic math courses and Algebra 1 courses, with a dual emphasis on arithmetic (34 percent of the time) and algebra (43 percent of the time). The algebra covered in Pre-algebra was extremely narrow in focus, limited to expressions and linear equations. Geometry courses emphasized geometry content (78 percent of instructional time).

For mathematics, the big news was not so much the content covered in traditional courses but rather, in comparison to the NCTM *Standards*, the content *not* covered. None of the math



courses studied gave significant attention to statistics, probability, or discrete mathematics. Pre-calculus courses did give some attention to probability, but only the most elementary probability topics. For example, Pre-calculus courses did not include empirical probability, conditional probability, or any attention to discrete or continuous distributions.

While Algebra 1 looked pretty much like Algebra 1 wherever it was found, Biology courses differed dramatically one from another. Some Biology courses looked more like broad survey courses of all science than they looked like Biology courses. Other Biology courses covered all of the main content areas in biology (biology of the cell, human biology, biology of other organisms, and biology of populations). Other Biology courses were survey courses of all biology content but with an additional emphasis on chemistry. Still other Biology courses focus almost exclusively on the content of biology of other organisms. The data from our sample suggest that knowing a student has taken high school Biology says relatively little about what content that student has studied. The same can be said for Life Science courses, which were essentially Biology courses themselves.

Although mathematics courses focussed on relatively fewer topics than science courses, the depth of instruction did not differ much between mathematics and science. Depth of instruction was defined as the number of different ways that a topic was taught (mode of instruction) in combination with the number of different intended student outcomes (e.g., understanding, memorization, computation). What was most striking was the general lack of depth of instruction for the courses in the sample. On average, a topic was taught in only 3 or 4 of the possible 63 combinations of modes of instruction and intended student outcomes defined for this study. This finding varied little from course type to course type and held for both mathematics and science.

How Those Topics Are Taught

Both mathematics and science courses were dominated by exposition, either verbal or written, as the primary mode of instruction. In mathematics, exposition was especially high in the lower-level courses, consuming two-thirds to three-fourths of instructional time. In science, reliance on exposition as the mode of instruction was less predictable, at least by course level. In both subjects and for virtually all of the course types studied, students spent the majority of their time either being talked to by the teacher or working independently at their desks. On average and for both math and science, one-third of the time was spent in seatwork, while only 25 percent of the time was spent in class discussion and small-group work.

There was very little lab work in either mathematics or science. What little lab work was done in mathematics consisted almost entirely of drill and practice at a computer terminal. In science, half of the courses in the log sample spent 5 percent or less of instructional time in lab work. The relative emphasis on lab work was specific to a particular course section and did not vary by course type. For example, the relative emphasis on lab work was no greater for chemistry courses than for physical science courses.

In neither mathematics nor science was there any field work to speak of. Nor did either subject involve students much in graph work, with only 1 percent of instructional time spent on graph work in science and a surprisingly low 4 percent of instructional time for graph work in mathematics.

One bright spot in an otherwise disappointing profile of instruction was the use of pictorial models in science. On average, 15 percent of science instructional time involved pictorial models; there was relatively little variance in the use of pictorial models across different science course types.

What emerges, then, from the information on modes of instruction is a great deal of teacher lecture and student independent seatwork, with very little emphasis on active engagement of students in the construction of their own knowledge. The gap between actual practice and the espoused curriculum reforms of the late 1980s was especially large.

Summary and Conclusions

The data from *Reform Up Close* provide a largely positive picture of the effects of state, district, and school standard-setting activities. As a result of higher standards, more high school students

were receiving more worthwhile math and science instruction in 1990 than ever before.

The best news is that the content of mathematics and science courses appeared not to have been compromised by increased enrollments. One might have hoped, however, that the pedagogical strategies employed by teachers would have expanded to accommodate the instructional needs of the greater diversity of students. Unfortunately, this was not the case. Throughout the sample of mathematics and science courses, instruction looked quite traditional. Emphasis was on teacher lecture and student independent seatwork.

In 1990-91, the enacted curriculum in high school mathematics and science was not at all in alignment with the curriculum reform toward higher-order thinking and problem-solving for all students. In mathematics, there were far too many remedial and basic courses with essentially arithmetic as content. Statistics, probability, and discrete mathematics, content areas emphasized in the new curriculum standards, received virtually no attention in any of the courses studied, including advanced courses. All math courses reflected a heavy emphasis on exposition and equations, with little emphasis upon modelling, real-world problems, and data application. The emphasis remained heavily on memorization and computation.

In science, the picture was similar. Science courses made little to no use of field work. Nearly half of the science courses allocated less than 5 percent of instructional time for lab work, and approximately half of the courses studied allocated less than 10 percent of instructional time to collecting data. Instead, the emphasis was heavily on memorizing facts and understanding concepts through lecture and textbook presentation. Clearly, the current curriculum reforms have their work cut out for them.

As for curriculum policymaking, none of the six states and eighteen districts had anything like a comprehensive approach to supporting the ambitious math and science curriculum reforms of 1989. Teacher empowerment reforms appeared to coexist with curriculum control measures in a sort of uneasy peace. Neither type of initiative appeared to give much recognition to the other. Rather, they coexisted in ways that left unresolved tensions that each created for the other.

Regardless of whether curriculum control or teacher empowerment ultimately becomes the preferred reform mechanism, staff development would appear to play a crucial role. However, we saw little by way of staff development that appeared up to the challenges ahead. Most staff development we found was fragmented and piecemeal, identified and delivered by persons distant from the classroom, and with little, if any, explicit connection to strengthening academic instruction.

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Examining Opportunity to Learn Standards

In its 1992 report, *Raising Standards for American Education* the National Council on Education Standards and Testing called for the development of "school delivery standards" to help assess a school's capacity and performance. In response to this report, the National Governors' Association began looking at how states might address the issue of SDS.

During the course of NGA's work and the development of the Clinton Administration's Goals 2000 Act, the terminology shifted from school delivery standards to "opportunity to learn" standards (OTL).

Opportunity to learn describes the "enacted curriculum as experienced by the student," says Andrew Porter in his paper, *Defining and Measuri ng Opportunity to Learn*. In the past, he says, greatest emphasis has been placed on the content of instruction, the particular concepts, skills and applications that are to be taught. But OTL has also included the pedagogical quality of instruction and the resources that are available to students and teachers as instruction takes place.

School delivery/opportunity to learn standards were instituted to prevent students from receiving a poor education, says Porter. There are at least three ways this might be done, he explains.

1. Standards might present a vision of good practice, presenting detailed accounts of effective instructional practices and school strategies in support of the goal of challenging content for all students.

2. The standards might provide a framework for a school-process indicator system that would describe in what ways and to what extent instruction in schools are consistent with the vision.

3. The standards might be the basis for school-by-school accountability. However, this is the least attractive use of OTL standards. Using them for school accountability is likely to shift attention away from outcomes and back to processes, something that has already failed to have the desired effects.

For more information on OTL, please see these publications by CPRE researchers:

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About the Authors

Andrew C. Porter is a professor of educational psychology and director of the Wisconsin Center for Education Research at the University of Wisconsin-Madison. He has published in the areas of research on teaching; education policy analysis; student and teacher assessment; and psychometrics, especially the problem of measuring change. Funding for his current work comes from the Office of Educational Research and Improvement, including CPRE.

Michael W. Kirst is professor of education and business administration at Stanford University and a faculty affiliate with the Department of Political Science. Dr. Kirst also is co-director of Policy Analysis for California Education (consortium of Stanford, UC Berkeley, and USC) and the Stanford representative of CPRE.

Eric Osthoff is a graduate in Educational Policy Studies at the University of Wisconsin-Madison, and a program assistant at the Center on Organization and Restructuring of Schools.

John L. Smithson is a doctoral candidate in Educational Policy Studies at the University of Wisconsin-Madison. In addition to his work on CPRE's Reform Up Close, his interests include mixed research methodologies and the development of Opportunity to Learn measures.

Steven A. Schneider is currently program director of Science and Mathematics at Far West Regional Laboratory and the director of Woodside Research Consortium. Dr. Schneider has extensive experience is the area of program evaluation, research, and teaching in the areas of science, math, and technology.

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Issues and Strategies in Systemic Reform
Susan H. Fuhrman and Diane Massell
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For further information on CPRE publications contact Pat Michaels at CPRE, Carriage House at the Eagleton Institute of Politics, Rutgers University, 86 Clifton Avenue, New Brunswick, NJ 08901-1568; 908/932-1331.

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Susan H. Fuhrman
Director, The Policy Center
Co-Director, The Finance Center
Eagleton Institute of Politics
Rutgers University

Allan R. Odden
Co-Director, The Finance Center
Wisconsin Center for Education Research
University of Wisconsin-Madison

William H. Clune
Wisconsin Center for Education Research
University of Wisconsin-Madison

David K. Cohen
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